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Substitution Elasticity and Gains from Trade Variety in South Korea*

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Abstract

Purpose – Recent international studies have largely focused on measuring the welfare gains from increased trade varieties. To adequately capture the variety gains, it is of importance to estimate the elasticity of substitution between varieties of trade goods because it is one of the key parameters to determine the magnitude of the variety gains. Using the import data of South Korea, this paper shows that the elasticities vary substantially across the estimators, which affects the magnitude of the gains from trade.

Design/methodology – Empirical studies working on the gains from trade variety have heavily depended on the estimation methods for the elasticity of substitution between trade varieties, developed by Feenstra (1994) and refined by Broda and Weinstein (2006). We estimate and compare the estimated elasticities for 8,945 HS 10 goods of South Korea, obtained from the three estimation methods: Feenstra's weighted least square (F-WLS), Feenstra's feasible generalized least square (F-FGLS), and Broda and Weinstein's feasible generalized least square (BW-FGLS).

Findings – Using the estimated elasticities from the F-FGLS, considered as a suitable estimator, A typical Korean consumer saved 228 dollars per year by the greater access to new import varieties. This leads to gains from imported variety of 2.06% of GDP. In 2017, a typical Korean consumer would gain by 611 dollars, compared with 2000. China is the country with the largest contribution (28.4%), followed by Japan and USA. About 50% of all the welfare gains come from the imports from the three main trade partners. The Southern Asian countries are more important to the South Korean welfare gain than the Western European countries.

Originality/value – Existing studies have chosen one of the methods without any criterion for the choice and then estimated the elasticities of substitution between varieties of trade goods. This paper focuses on the estimation specifications and methods as the cause of the disparity in estimated elasticities and welfare gains from trade variety. According to the Ramsey RESET and White tests, the F-FGLS estimates are relatively better compared to the F-WLS and BW-FGLS estimates. As another contribution, this paper provides the first measure of the welfare gains from trade variety for South Korea, using the estimated elasticities of substitution between trade varieties.

Keywords: Elasticity of Substitution, Gain from Trade Variety, New Varieties
JEL Classifications: F12, F14

1. Introduction

The recent theories of international trade with heterogeneous firms have focused on the role of trade variety in the gains from trade,[1] instead of traditional comparative advantage. Because the elasticities of substitution between goods (varieties) produced in different countries govern the strength of the variety gains,[2] it is very crucial to measure the elasticities of substitution. However, estimating the elasticities of substitution is not easy because of no

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availability of real prices in standard trade data and simultaneity in a system of import demand and export supply.

Thankfully, Feenstra (1994) provided methods with a nested CES structure to estimate the elasticities of substitution between varieties in disaggregate trade data. He proposed an instrumental variables (IV) technique that yields asymptotically consistent and efficient estimates. To be practical, he suggested a weighted least square (WLS) without a help of external variables, which is equivalent to the IV estimator, and a feasible generalized least square (FGLS) to get the most efficient estimator. To correct for measurement error and heteroscedasticity in the Feenstra's methods, Broda and Weinstein (2006) suggested a feasible generalized least square (FGLS) and a grid search method for some economically infeasible elasticities less than unity. They successfully estimated the elasticities of substitution between import varieties for about 30,000 goods from the US official import statistics. Another key aspect of Broda and Weinstein (2006) is that they provided the first measure of the welfare gains from trade variety for an entire country, using the estimated elasticities of substitution between trade varieties. The welfare gain from new imported varieties for the US consumers amounts to 2.6% of GDP over the period 1972-2001.

The Feenstra's original methods and extended ones have been widely used because they are more tractable and robust than any other method to estimate good-specific elasticities of substitution from dis-aggregated trade data. Chen and Ma (2012) showed that the Chinese welfare gain as a result of growth in import variety amounts to 4.9% of GDP, using tens of thousands elasticities of substitution. Mohler and Seitz (2012) showed that within the 27 EU countries, especially newer and smaller members exhibit high gains from newly imported varieties. For example, the consumers in Estonia gained 2.80% of GDP. Ossa (2015) estimated the elasticities of substitution for the 50 largest economies in the world, and showed that a move from complete autarky to 2007 levels of trade would increase real income by only 16.5% on average. Broda et al. (2017) found that import variety growth between 1994 and 2003 raised world permanent income by 17%, using the elasticities of substitution estimated at 6-digit HS import data for 73 countries.

However, there have been little discussions about the difference in estimated elasticities across the estimation methods and their statistical performance. Apparently doing such exercises is computationally cumbersome when estimating tens of thousands elasticities of substitution from highly disaggregated data. Existing studies have chosen one of the methods without any criterion for the choice and then estimated the elasticities of substitution between varieties of trade goods. Consequently, the gains from trade variety vary systematically across them and erratically estimated elasticities naturally incur failure to capture the exact gains from trade variety. This paper compares the estimation specifications and methods as the cause of the disparity in estimated elasticities and welfare gains from trade variety.

This paper focuses on South Korea as a representative small open economy. Even though South Korea is recognized as one of the most successful countries that have made great strides in trade variety and its gains from trade seem to be undoubtedly large, there is no systematic

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[1] Melitz (2003), Chaney (2008), Arkolakis et al.(2012), Melitz and Redding (2014), Feenstra and Weinstein (2017), Feenstra (2010/2018), Brooks and Pujolas (2019), Arkolakis et al.(2019).

[2] The elasticity of substitution governs the effects of trade variety on import price and incomes (Feenstra, 1994; Broda and Weinstein, 2006; Arkolakis et al., 2012; Ossa, 2015: Brooks and Pujolas, 2019), trade flows (Chaney, 2008), trade balance adjustment (Imbs and Mejean, 2015), free trade agreements (Romalis, 2007), the international transmission of business cycles (Heathcote and Perri, 2002), the optimal tariff (Broda et al., 2008, Soderbery, 2018), and the terms of trade (Kang, 2019).

research on how much the variety expansion benefits South Korea's welfare. This paper provides the first measure of the welfare gains from trade variety for South Korea. We estimate and compare the estimated elasticities for 8,945 HS 10 goods of South Korea, obtained from the three estimation methods: Feenstra's weighted least square (F-WLS), Feenstra's feasible generalized least square (F-FGLS), and Broda and Weinstein's feasible generalized least square (BW-FGLS). The three estimators do not always provide economically feasible values for the elasticities of substitution. In that case we use a grid search proposed by Broda and Weinstein (2006). We find that the median elasticity of substitution from the F-FGLS (4.76) are lower than those from the F-WLS (5.99) and the BW-FGLS (6.28).

From the comparison of individual elasticities, we confront a question: Which one is best? In order to answer the question, this paper implements some tests for misspecification and heteroscedasticity to decide which estimator performs best. According to the Ramsey RESET and White tests, the F-FGLS estimates are relatively better compared to the F-WLS and BW-FGLS estimates. With the estimated elasticities of substitution, this paper provides a measure of the South Korean consumer gains from import varieties over the period 2000-2017. The consumer gains as a percentage of South Korean GDP are estimated to be 1.55% from the F-WLS, 2.06% from the F-FGLS, and 1.49% from the BW-FGLS. The variety gains vary significantly across the estimators as a result of the different sizes in the estimated elasticities. Since the F-FGLS estimates are performing best, we document here that the variety gain in South Korea is 2.06% of GDP. The F-WLS and BW-FGLS account for an under-statement of variety gain by 0.51% point and 0.57% point, respectively. For clarity, this paper provides absolute dollar amounts of the variety gain, using the results from the F-FGLS. A typical Korean consumer can save 228 dollars per year by the greater access to new import varieties. We also compute the gains from trade variety as a fraction of GDP (GFV). The gain from import variety in South Korea is 2.06% of GDP between 2000 and 2017. In absolute value, the welfare gain is 31.5 billion dollars, and the welfare gain per capita is 611 dollars. In 2017, a typical Korean consumer would gain by 611 dollars, compared with 2000. Lastly, we provide the country contribution in the welfare gain. The country with the largest contribution to the gain over the period is China (28.4%), followed by Japan (10.6%) and USA (9.32%). About 50% of the GFVs come from the three countries. The contributions of the Southern Asian countries having acquired the growing role in the world trade are larger than ones of the Western European countries.

The rest of the paper is organized as follows: Section 2 briefly reviews the methodologies developed by Feenstra (1994) and refined by Broda and Weinstein (2006) to estimate the elasticities of substitution. Section 3 lays out the estimated elasticities for South Korean import goods, and compares the sizes of them across the three estimators. Section 4 presents which estimator performs best by implementing the Ramsey TESET and White tests. Section 5 examines the magnitude and source of South Korean variety gains. Section 6 concludes.

2. Model Specifications and Estimation Methods

2.1. System of Import Demand and Export Supply

To obtain the elasticity of substitution between varieties of a good, we use a model of demand and supply, based on Feenstra (1994) and Broda and Weinstein (2006). Let us focus on the CES sub-utility from imported varieties of goods in period t. A variety is defined as a good g imported from a country υ as in Armington (1969).

$$M_{gt} = \left(\sum_{\upsilon \in I_{gt}} d_{g\upsilon t}^{\frac{1}{\sigma_g}} m_{g\upsilon t}^{\frac{\sigma_g - 1}{\sigma_g}} \right)^{\frac{\sigma_g}{\sigma_g - 1}} \tag{1}$$

where a good (g) is consisting of several varieties $(\upsilon \in I_{gt})$. $d_{g\upsilon t}$ denotes a random taste parameter of each variety, and $m_{g\upsilon t}$ denotes the aggregate quantity of each variety. $\sigma_g > 1$ is the elasticity of substitution between imported varieties of good g.

The demand for variety υ can be derived from the utility maximization with the minimum unit-cost function (ϕ_{gt}). However, real prices are unavailable in all standard international trade dataset. Kemp (1962) pointed that instead of unit vales, using shares helps to avoid the problem of measurement error. The demand is expressed into the market share to avoid a potential measurement error imparted from the use of unit values $\left(s_{g\upsilon t} = p_{g\upsilon t} m_{g\upsilon t} / \sum_{\upsilon \in I_{gt}} p_{g\upsilon t} m_{g\upsilon t}\right)$. The change in share equation becomes

$$\Delta \ln s_{g\upsilon t} = \varphi_{gt} - (\sigma_g - 1)\Delta \ln p_{g\upsilon t} + \varepsilon_{g\upsilon t} \tag{2}$$

where φ_{gt} is the difference in the unit cost function, which is acting as a random effect and $\varepsilon_{g\upsilon t} = \Delta \ln d_{g\upsilon t}$.

The upward-sloping supply equation with an inverse supply elasticity $\omega_g \geq 0$ and a random technology factor $\tau_{g\upsilon t}$ is given by

$$\Delta \ln p_{g\upsilon t} = \psi_{gt} + \frac{\omega_g}{1+\omega_g} \Delta \ln s_{g\upsilon t} + \delta_{g\upsilon t} \tag{3}$$

where ψ_{gt} and $\delta_{g\upsilon t}$ capture any random changes in the total expenditure and the technology factor, respectively.

To eliminate good and time specific unobservable φ_{gt} and ψ_{gt}, we difference the demand and supply equations by a reference country (variety)'s prices and shares, denoted by r. [3]

$$\Delta^r \ln s_{g\upsilon t} = -(\sigma_g - 1)\Delta^r \ln p_{g\upsilon t} + \epsilon_{g\upsilon t}^r \tag{4}$$

$$\Delta^r \ln p_{g\upsilon t} = \frac{\omega_g}{1+\omega_g} \Delta^r \ln s_{g\upsilon t} + \delta_{g\upsilon t}^r \tag{5}$$

Assume that the supply and demand errors vary independently across time and product space, $\mathrm{E}(\epsilon_{g\upsilon t}^r \delta_{g\upsilon t}^r) = 0$ and define $\rho_g \equiv \frac{\omega_g(\sigma_g - 1)}{1+\omega_g \sigma_g}$. By multiplying equations (4) and (5), and dividing them by $(\sigma_g - 1)(1 - \rho_g)$, we obtain a single equation, from which the parameter σ_g will be extracted:

$$Y_{g\upsilon t} = \theta_{g1} X_{1g\upsilon t} + \theta_{g2} X_{2g\upsilon t} + u_{g\upsilon t} \tag{6}$$

[3] Note that in our study the reference country is selected on the criterion that it is imported with the highest value. In other words, the reference is chosen separately for every good.

$$\text{where } Y_{gvt} \equiv \left(\Delta^r \ln p_{gvt}\right)^2 \tag{7}$$

$$X_{1gvt} \equiv \left(\Delta^r \ln s_{gvt}\right)^2 \tag{8}$$

$$X_{2gvt} \equiv \left(\Delta^r \ln s_{gvt}\right)\left(\Delta^r \ln p_{gvt}\right) \tag{9}$$

$$\theta_{g1} \equiv \frac{\rho_g}{(\sigma_g - 1)^2 (1 - \rho_g)} \tag{10}$$

$$\theta_{g2} \equiv \frac{2\rho_g - 1}{(\sigma_g - 1)(1 - \rho_g)} \tag{11}$$

Once $\hat{\theta}_{g1}$ and $\hat{\theta}_{g2}$ are obtained from estimating equation (6), we solve for $\hat{\sigma}_g$, using equations (10) and (11). As long as $\hat{\theta}_{g1} > 0$,[4] $\hat{\sigma}_g$ is extracted as;

$$\hat{\sigma}_g = 1 + \left(\frac{2\hat{\rho}_g - 1}{1 - \hat{\rho}_g}\right)\frac{1}{\hat{\theta}_{g2}} \tag{12}$$

2.2. Feenstra's Methods and Extensions

2.2.1. Feenstra's WLS (F-WLS)

Since we assume that the supply and demand errors are assumed to be independent, we have $\mathrm{E}\left(\epsilon^r_{gvt}\delta^r_{gvt}\right) = 0$. However, the error term, u_{gvt}, is correlated with both prices and expenditure shares contained X_{1gvt} and X_{2gvt}. As a results from direct estimation of equation (6), we do not get a consistent estimates of $\hat{\theta}_{g1}$, $\hat{\theta}_{g2}$, and then $\hat{\sigma}_g$. To avoid an endogeneity bias, instrumental variable (IV) estimation would be needed. Feenstra (1994) demonstrated that an IV estimation on equation (6) with product dummies as instruments produces consistent estimates. He proposed a simple method to get consistent estimates because it is impossible to obtain valid instrumental variables. The prices and shares are averaged over time and weighted by the number of periods in each variety (country). Running OLS on the averaged and weighted equation, which is a weighted least square regression (WLS) without external instruments, is equivalent to the IV estimation.

Feenstra (1994) introduced a constant (α) into the model to correct for a potential measurement error caused by using the unit-prices instead of real price in standard data set.

$$\bar{Y}_{gvt} = \alpha + \theta_{g1}\bar{X}_{1gvt} + \theta_{g2}\bar{X}_{2gvt} + \bar{u}_{gvt} \tag{13}$$

where upper bars on variables denote sample means over time. Under the F-WLS, as our first estimator, we will estimate $\hat{\theta}_{g1}$ and $\hat{\theta}_{g2}$, and then solve quadratic equations (10) and (11) to obtain $\hat{\sigma}_g$ as long as $\hat{\theta}_{g1} > 0$.

2.2.2. Feenstra's FGLS (F-FGLS)

The above F-WLS estimator is consistent but it is not the most efficient one because of the

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[4] If $\hat{\theta}_{g1} < 0$ and $\hat{\theta}_{g2} < 0$, however, it is impossible to obtain economically feasible value for $\hat{\sigma}_g$. Thanks to the grid search by Broda and Weinstein (2006), economists have successfully estimated elasticities of substitution.

presence of heteroscedasticity. Feenstra (1994) suggested a feasible GLS (FGLS) to get the most efficient estimator. In a first step, we obtain the error terms via equation (13). Then, the observations are weighted by the inverse of the estimated standard errors to correct for assumed heteroscedasticity. At the last step, we re-estimate equation (13) to obtain efficient estimates of $\hat{\sigma}_g$ and $\hat{\rho}_g$. This procedure corresponds to the weighting matrix that is optimally used in 2-step GMM estimation.

2.2.3. Broda and Weinstein's FGLS (BW-FGLS)

Broda and Weinstein (2006) refined the Feenstra's correction for measurement error. Instead of a constant, they include a term, $\frac{1}{T}\sum_t\left(\frac{1}{m_{gvt}}+\frac{1}{m_{gvt-1}}\right)$, that is inversely proportional to the quantity of varieties and the number of periods the variety exists. Instead of the inverse of the estimated residuals to correct for heteroscedasticity in F-FGLS, Broda and Weinstein (2006) weighted the data by $T^{3/2}\left(\frac{1}{m_{gvt}}+\frac{1}{m_{gvt-1}}\right)^{-1/2}$, by assuming that the variance of each observation of a variety is inversely related to the imported quantity.

2.2.4. Broda and Weinstein's Grid Search (BW-GS)

Unfortunately, if $\hat{\theta}_{g1} < 0$ and $\hat{\theta}_{g2} < 0$, each of the above estimators does not always provide economically feasible values for $\hat{\sigma}_g$ and $\hat{\rho}_g$. In that case we use a grid search proposed by Broda and Weinstein (2006) to minimize the GMM function objective function corresponding to equation (6). Explicitly, we choose $\hat{\sigma}_g$ from a minimum of 1.05 to a maximum of 150.5 at equally spaced intervals of 0.05 to minimize $G^*(\sigma_g,\rho_g)WG^*(\sigma_g,\rho_g)$, where $G^*(\sigma_g,\rho_g)$ is the sample analog of the moment condition $G^*(\sigma_g,\rho_g)=E_t(u_{gvt})=0,\forall v$, and W is a positive definite weighting matrix.

3. Estimated Substitution Elasticities in South Korea

We use the import data at 10-digit Harmonized Tariff System (HS 2010) obtained from the *Korea Trade Association database* over the period 2000-2017. The data on the value and quantity allows us to calculate unit price for each product. A variety is defined as a good being imported from a particular country as in Armington (1969), and a good can be defined at different aggregation levels in the HS codes.

We estimate the elasticities of substitution for 8,945 HS 10 goods over the 17 years, using the F-WLS, F-FGLS, and BW-FGLS methods. Table 1 presents some descriptive statistics of the estimates from the three estimators, including infeasible elasticities of substitution ($\hat{\sigma}_g < 1$). The first result is that the elasticities are very different across the estimators. The median elasticity of substitution from the F-FGLS (3.70) are lower than those of the F-WLS (4.63) and BW-FGLS (5.44). The maximum and minimum values are quite different across the estimation methods, and the minimum values are significantly less than unity. The second result is that each of the three estimators does not always provide economically feasible values for $\hat{\sigma}_g \geq 1$. Evidently, the summary statistics are significantly contaminated because the fractions of infeasible elasticities ($\hat{\sigma}_g < 1$) are about one quarter, ranging from 22% to 26%.

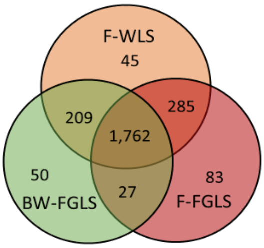
Table 1. Estimated Elasticities

Method	N. O.	Median	Mean	Maximum	Minimum	Infeasible Sigmas
F-WLS	8,945	4.63	8.98	2,432.2	-390.37	2,393 (26%)
F-FGLS	8,945	3.70	8.18	3,696.1	-137.44	2,048 (22%)
BW-FGLS	8,945	5.44	10.05	2,867.0	-150.70	2,157 (24%)

Note: The elasticities are estimated at the HS-10 level over the 17 years from 2000-2017. The summary statistics include infeasible elasticities of substitution.
Source: Author's estimation using KITA database.

Fig. 1 illustrates a Venn diagram on three sets of infeasible elasticities. The number of goods that are common to the three sets is 1,762, which is about 71% (=1,762/2,461). The number of goods that are not common to the corresponding two sets is 83 in the F-WLS, 45 in the F-FGLS, and 50 in the BW-FGLS. Both Table 1 and Figure1 highlight that the differences among the methods are quite significant, and the three estimators do not always provide economically feasible values. For the goods where $\hat{\sigma}_g < 1$, we use a grid search over the economically feasible values, proposed by Broda and Weinstein (2006).

Fig. 1. Infeasible Elasticity Sets

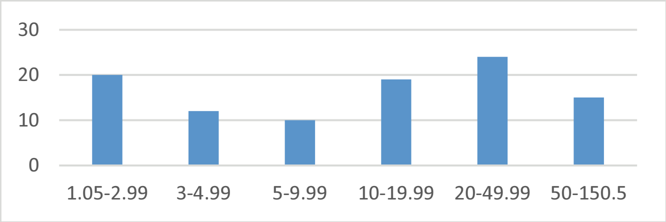


Note: The Venn diagram shows the three sets of infeasible elasticities, estimated from the F-WLS, F-FGLS, and BW-FGLS. The elasticities are estimated at the HS-10 level over the 17 years from 2000-2017.
Source: Author's estimation and calculation using KITA database.

Fig. 2 reports the estimated elasticities (sigmas) obtained from BW-GS for the F-FGLS estimates with less than unity (2,048). Apparently, the grid search generates a polarized distribution of the elasticity estimates. 20% of grid searched estimates range from 1.05 to 2.99, 12% range from 3 to 9.99, and 58% are greater than 10. The grid search tends to lead to elastic (less differentiated) estimates, implying that it places less weight on the gains from variety.

Table 2 presents some descriptive statistics of the elasticity estimates corrected by the grid search. There are three noteworthy results. First, the median and mean values are greater than those in Table 1 because the estimated elasticities less than 1 are corrected by the grid search. Second, similar to Table 1, the median (mean) elasticity of substitution from the F-FGLS is still lower than those from the F-WLS and BW-FGLS. The median elasticities are 4.76 in the F-WLS, 5.99 in the F-FGLS, and 6.28 in the BW-FGLS respectively, which implies that the consumer's gains from trade variety may be significantly variant across the estimation scheme. Compare to the F-WLS and BW-FGLS, the F-FGLS generates less elastic (more differentiated) estimates, and might have a bigger effect of variety change on import price and welfare gains. Third, the median values are much less than the mean values, which denotes that the distribution of estimated elasticities is highly skewed towards the right.

Fig. 2. Grid Search Results for Elasticities



Note: The horizontal axis denotes the range of BW-GS elasticities for F-FGLS infeasible ones (2,048). The vertical axis denotes the percentage (%) of each range.
Source: Author's estimation and calculation using KITA database.

Table 2. Estimated Elasticities Corrected by BW-GS

Method	N. O.	Median	Mean	Maximum	Minimum
F-WLS with Grid Search	8,945	5.99	10.63	2,432.2	1.00
F-FGLS with Grid Search	8,945	4.76	9.47	2,867.0	1.00
BW-FGLS with Grid Search	8,945	6.28	11.31	3,696.1	1.01

Note: The elasticities are estimated at the HS-10 level over the period, 2000-2017. The grid-searched estimates for infeasible elasticities are censored at 150.05.
Source: Author's estimation and calculation using KITA database.

In order to confirm the above results, we need to compare individual elasticities at the 10-digit level. Given the thousands of elasticities, I refrain from laying out all estimates in detail, but report 16 individual elasticities in Table 3. In the case of $\hat{\sigma}_g < 1$, the elasticities are corrected by the grid search. The magnitude in the estimated elasticities is very sensitive to the choice of the estimator. For example, the estimated elasticities of the product, HS code 3823110000, are greater than 1. But using the F-FGLS (6.23), the estimated elasticity is even lower, and the estimated elasticities from the F-WLS (9.51) and BW-FGLS (9.28) are similar. The estimated elasticities of the product, HS code 3823120000, are significantly different across the estimation methods, and the elasticity from the BW-FGLS is the lowest. As a last example, all of the estimated elasticities of the product, HS code 3824600000, are a lot lower than 1. We apply the grid search to get an economically feasible value proposed by Broda and Weinstein (2006). The estimated elasticity is 1.10, which minimizes the GMM objective function implied by the IV estimation. The comparison of individual elasticities also implies that the choice of the estimators would results in different welfare gains from import varieties.

Table 3. Comparison of Individual Estimated Elasticities

HS Code	Product Name	F-WLS	F-FGLS	BW- FGLS	BW-GS
3823110000	Stearic acid	9.51	6.23	9.28	
3823120000	Oleic acid	11.6	9.7	6.84	
3823130000	Tall Oil Fatty Acids	7.02	**-2.47**	13.2	17.6
3823191000	Palmitic acids	6.32	6.89	5.20	
3823192000	Acid oils from refining	9.43	7.32	10.6	
3823701000	Cetyl alcohol	2.98	5.35	1.98	
3823702000	Oleyl alcohol	74.9	46.2	19.3	
3823704000	Lauryl alcohol	5.25	4.32	6.37	
3824100000	Prepared binders for foundry moulds or cores	1.59	1.91	**0.26**	4.05
3824200000	Naphthenic acids, their water-insoluble salts and their esters	29.4	13.7	16.34	
3824300000	Non-agglomerated metal carbides mixed together or with metallic binders	**-2.66**	**-0.39**	3.84	2.72
3824400000	Prepared additives for cements, mortars or concretes	2.93	3.22	3.17	
3824600000	Sorbitol other than that of subheading 2905.44	**-28.3**	**-13.7**	**-52.6**	1.10
3824710000	Containing acyclic Hydrocarbons perhalogenated only with fluorine and chlorine	4.30	4.27	6.74	
3824902300	Detergents based on trichlorotrifluoroethane	1.35	1.98	3.21	
3824902400	Intermediate products of the antibiotics manufacturing process	7.90	4.34	5.97	

Note: The estimates of grid search for infeasible ones are censored at 150.05. Since the bold ones denote economically infeasible elasticities, they are replaced by ones from the grid search.
Source: Author's estimation using KITA database.

4. Tests for Misspecifications and Heteroscedasticity

As it is stated above, the choice of an estimator method is important because the sizes in the estimated elasticities change very much and determine the magnitude of the welfare gains. This is calling into a question which estimator performs best. The common concerns in estimating the elasticities of substitution are measurement error and heteroscedasticity. Recall that the measurement error in international trade data is inevitable because of using unit prices, instead of real prices. Feenstra (1994) and Broda and Weinstein (2006) introduced an additional term to correct for a potential measurement error caused by using unit-prices. The Ramsey RESET test can help to detect the irrelevance of the additional term. We can test whether an included variable is irrelevant by leaving it out of the regression, and implement the RESET test on the remaining explanatory variables. If we fail to reject a null hypothesis, there is evidence that the variable which was left out here might be irrelevant. Another problem is heteroscedasticity in the data, even if they corrected for heteroscedasticity by weighting the data. A general test for heteroscedasticity is the White test.

In Table 4, the first row shows the number and percentage of tests where the null hypothesis is not rejected at the 10% confidence level. If the null hypothesis of correct specification is rejected, misspecification is still present. 40.6% of F-WLS elasticities have a correct specification, which implies that 59.4% still have the problem of misspecification even with the constant term. In the F-FGLS, the acceptance percentage is 43.3% which is the highest among the three methods. But 56.7% are suffering from misspecification. In BW-FGLS, only 36.4% are free from the problem of misspecification. 63.6% are suffering from misspecification, even with allowing the measurement error to depend inversely proportionally on each variety's quantity sold and the number of periods. The estimated elasticities obtained from the F-FGLS tend to be less suffer from the misspecification problem. Despite the data is corrected by some additional terms, however, measurement error or any other misspecification is still present in many of the estimated elasticities.

Next, we conduct a White test with the null hypothesis of homoscedasticity. In the F-WLS, the null-hypothesis is not rejected at 17.6% of the total estimated elasticities. Heteroscedasticity is still present in 82.4% of the estimated elasticities. In the F-FGLS, despite weighting by the inverse of the estimated standard errors, heteroscedasticity is still present in 76.5% of the estimated elasticities. The issue of heteroscedasticity is partly cured by weighting the data by the inverse of the estimated standard errors. In BW-FGLS, 78.8 % of the elasticities suffer from heteroscedasticity even if the variance of each observation is inversely related to the imported quantity. The F-FGLS estimator are less suffering from heteroscedasticity. According to the above two tests, we confirm that the F-FGLS is relatively better, compared to the rest of two estimation methods.

Table 4. Acceptance Percentage of Null Hypothesis

	F-WLS		**F-FGLS**		**BW-FGLS**	
	# of tests	%	# of tests	%	# of tests	%
Ramsey Test	3,873	40.6%	4,114	43.3%	3,255	36.4%
White Test	1,574	17.6%	2,102	23.5%	1,896	21.2%

Note: The table shows the number and percentage of tests where the null hypotheses of correct specification and homoscedasticity are not rejected. The total number of the estimated elasticities is 8,945.

Source: Author's estimation and calculation using KITA database.

5. Magnitude of Trade Variety in South Korea

5.1. Capturing Variety Gain

We are ready to calculate the consumer's gains from new import varieties with the estimated elasticities of substitution. Based on the new trade theory, Feenstra (1994) defined the exact import price index with the impact of new and disappearing varieties for a single imported good, and then measured consumer welfare gain from a changing set of import varieties. The exact import price index for a good is defined as (Feenstra (1994)'s Theorem 1)

$$\frac{\pi_{gt}(I_{gt})}{\pi_{gt-1}(I_{gt-1})} = P_g(I_g)\left(\frac{\lambda_{gt}}{\lambda_{gt-1}}\right)^{\frac{1}{\sigma_g - 1}} \tag{14}$$

where $P_g(I_g)$ is the conventional import price index for good g in the common variety set between times $(I_g = I_{gt-1} \cap I_{gt})$, and the lambda (λ) ratio augmented by $\frac{1}{\sigma_g - 1}$ captures the gains from a changing set of import varieties. The lambdas (λs) are defined, respectively, as

$$\lambda_{gt} = \frac{\sum_{v \in I_g} p_{vt} \cdot q_{vt}}{\sum_{v \in I_{gt}} p_{vt} \cdot q_{vt}}, \quad \lambda_{gt-1} = \frac{\sum_{v \in I_g} p_{vt-1} \cdot q_{vt-1}}{\sum_{v \in I_{gt-1}} p_{vt-1} \cdot q_{vt-1}} \tag{15}$$

The lambda ratio with $(1/(\sigma_g - 1))$, contains consumer's love of variety: as new import varieties appear, the lambda ratio becomes smaller, while as import varieties dis-appear, the lambda ratio becomes larger. The lambda ratio less than one indicates that a good experienced a positive growth of import varieties (new varieties is greater than disappearing ones).[5] In addition, consumers only loves differentiated import varieties: as a good is more differentiated (lower σ_g), the lambda ratio term is getting bigger. Consequently, increasing import varieties in a good with lower σ_g have a larger effect on the import price index and then welfare.

As done by Broda and Weinstein (2006), we aggregate the lambda ratio over all import goods $(g \in G)$. The ratio of the corrected import price index to the conventional import price index expresses the bias from ignoring the changes in import varieties. This is called the endpoint ratio (EPR).

$$\text{EPR} = \prod_{g \in G}\left(\frac{\lambda_{gt}}{\lambda_{gt-1}}\right)^{\left(\frac{\omega_{gt}}{\sigma_g - 1}\right)} \tag{16}$$

where the weights, ω_{gt}, are ideal log-changes at the goods, capturing the importance of the good in total expenditure. The EPR less than one means the upward bias of a conventional import price index compared to the variety-corrected import price index. It indicates a decrease in the import price index and then the consumers benefit from lower costs of imports.

Assume that the separability between import goods and domestically produced goods in

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[5] Since the λ ratio accounts for the importance of different varieties by using expenditure shares as weights, as a measure of variety growth, it is more sophisticated than just counting the number of new and disappearing varieties.

the Cobb-Douglas utility function (Krugman, 1980), the welfare gain from variety as a percentage of GDP (GFV) is derived from the disparity between the conventional overall price index of the economy and the overall price index of the economy taking into account variety changes. To express the variety gain only from import as a percentage of GDP, the inverse of the endpoint ratio (EPR) is weighted by the share of imports on the GDP (IS_t). The variety gains from trade as a percentage of GDP (GFV) is defined as:

$$\text{GFV} = \left(\frac{1}{EPR}\right)^{IS_t} - 1 \quad (17)$$

Alternatively, the consumer's variety gain from trade as a percentage of GDP can be interpreted as the gain via compensating variation required for consumers to be indifferent between the set of import varieties at the final and starting periods.

The welfare gain from import variety depends on the weighted aggregate lambda ratios, the elasticities of substitution, and import share in the total economic activity. The gain from variety is increasing in the total number of new varieties: the more new varieties are imported, the larger is welfare gain from variety. The lambda ratio includes the importance of new varieties: the higher the expenditure share on new varieties, the larger the gain from variety. The gain from variety is decreasing in the magnitude of the elasticity of substitution: the more differentiated varieties of a good, the larger is welfare gain from variety. The gain from variety is increasing in import share relative to the total economic activity.

5.2 Variety Gains in South Korea, 2000-2017

To obtain a measure of the gains from import variety, let us start with variety growth. Table 5 reports summary statistics for lambda ratios of 3,277 goods at the HS 10-digit level. The number of lambda ratio (3,277) is even smaller than one of the sigmas (8,945) because many of lambda ratios for goods that are not common in 2000 and 2017 cannot be calculated from the formula of the lambda ratio. The lambda ratio less than one indicates that the good experienced the number of import varieties increases, and vice versa. Over the period 2000-2017, the median lambda ratio is 0.932, expressing that a typical good in South Korean imports experienced a positive growth in import variety about 7.29%, and 0.42% annually.[6] These numbers imply substantial growth of import varieties in South Korea, and then high welfare gains for its consumers.

Table 5. Lambda Ratios

N. Observations	Median	Mean	5 Percentile	95 Percentile
3,277	0.932	0.984	0.241	1.293

Note: Lambda ratios are calculated at the HS-10 level over the period 2000-2017.
Source: Author's estimation and calculation using KITA database.

Using the calculated lambda ratios and estimated elasticities of substitution, we calculate the endpoint ratio (EPR), the bias in the conventional import price (Bias), and the variety gain as a percentage of GDP (GFV). Column (1) of Table 6 shows the EPRs. As long as the

[6] The growth rate of varieties in a good is calculated from the lambda ratio by the formula: Variety growth (1/lambda ratio)-1.

EPR is lower than 1, the changes of imported varieties have lowered the import price index. The South Korean consumers benefit from lower cost of imports and then obtain higher welfare gains. The EPRs are 0.954, 0.941, and 0.956, respectively. To put it differently, column (2) shows the bias of the conventional import price index (Bias). If the bias is positive, there is an upward bias. The change of import varieties decreases the import price index by 4.82%, 6.38%, and 4.60% over the whole period, and 0.28%, 0.37%, and 0.27% per year.[7] The differences in the estimated elasticities are reflected in the end-points ratios (EPR) and the biases of the conventional import price (Bias). As shown by Table 2, the estimated elasticities from the F-FGLS are lowly estimated, compared to those from the F-WLS and BW-FGLS. Correspondingly, the end-points ratio (EPR) from the F-FGLS estimates is lower and then the bias is greater. The difference between the F-FGLS and BW-FGLS estimates generates a gap of 0.015 in the end-points ratio (EPR) and 1.78% point in the bias.

Table 6. Variety Gains in South Korea

	End-points Ratio (EPR)	Bias	Variety Gain as a Percentage of GDP (GFV)
F-WLS	0.954	4.82%	1.55%
F-FGLS	0.941	6.38%	2.06%
BW-FGLS	0.956	4.60%	1.49%

Note: GFV is calculated by using the average import share, 33.3%, over the period 2000-2017.
The number of total import goods (i.e., the estimated elasticities) is 3,277.
Source: Author's estimation and calculation using KITA database.

To compute the gain from trade variety as a fraction of GDP (GFV), we weight the inverse of the end-points ratio by the import share. The average import share in South Korea for the 2000- 2017 period is 33.3%. As seen in Table 6, the variety gains vary significantly across the estimators: the GFVs are 1.55% in the F-WLS, 2.06% in the F-FGLS, and 1.49% in the BW-FGLS of South Korean GDP, respectively. Not surprisingly, the F-FGLS exhibits the highest GFV due to the relatively low elasticities of substitution. On the other hand, the F-WLS and BW-FGLS exhibit small GFVs due to the relatively high elasticities. The differences in the estimated elasticities are responsible for calculating consumer gains from variety. The F-FGLS estimator highlights an under-estimation of the variety gains from trade in the BW-FGLS by 0.56% point.

As noted before, a lot of the estimated elasticities still have the problems of misspecification and heteroscedasticity. It comes into a reasonable doubt that the variety gains obtained from using all of them would be inaccurate. We need to examine how much the welfare gains vary between when using all of elasticities and when using some elasticities of goods where the null hypotheses of both correct specification and homoscedasticity are not rejected. We narrow the sample to the goods (i.e., estimated elasticities) where the null hypotheses of both correct specification and homoscedasticity are not rejected, instead of the full sample (3,277). Table 7 shows the variety gains calculated by using the estimated elasticities having both correct specification and homoscedasticity. The weights, ω_{gt}, are ideal log-changes at the goods, capturing the importance of the good in total expenditure of 1,182, 1,479, and 1,320 goods. These individual shares sum up to one.

[7] % bias is defined as (1/EPR)-1, and % bias per year is defined as % bias/17.

The welfare gains are 1.42%, 1.92%, and 1.60%, respectively. Compared to the results in Table 7, the variety gains from the F-WLS and F-FGLS contract by 0.13% point and 0.14% point, whereas the variety gain from the BW-FGLS expands by 0.11% point. We find that narrowing the sample slightly changes the variety gains as a percentage of GDP (GFV), and does not affect our overall results of the variety gains.

Table 7. Variety Gains by Small Sample

	N. Ob.	End-points Ratio (EPR)	Bias	Variety Gain as a Percentage of GDP (GFV)
F-WLS	1,182	0.958	4.38%	1.42%
F-FGLS	1,479	0.944	5.93%	1.92%
BW-FGLS	1,320	0.955	4.71%	1.53%

Note: The variety gains are calculated by only using estimated elasticities having both correct specification and homoscedasticity.
Source: Author's estimation and calculation using KITA database.

The more noticeable result is that the disparity in the variety gains across the estimators is still persistent even with smaller sample. The F-FGLS exhibits the highest GFV (1.92%), as followed by the BW-FGLS (1.53%) and F-WLS (1.42%). It highlights that the choice of the estimators is more important rather than the issues of misspecification and heteroscedasticity in the Feenstra's system. The differences in elasticities incurred by the choice of an estimator has a substantial effect on the gains from import varieties.

5.3 Variety Gains as Dollar Amounts

Before moving to the next section, let us convert the welfare gains into absolute dollar amounts explicitly. Since the two tests reported that the F-FGLS is relatively better compared to the rest of two estimation methods, we provide absolute dollar amounts of the variety gains, using the estimated elasticities obtained from the F-FGLS. Over the 17 years, ignoring the change in the set of imported varieties has led to an upward bias in the South Korean import price index of 6.38%, and an annual bias of 0.37%. The average import value is 354 billion dollars over the 17 years. The 0.37% reduction in the import price would save South Korean consumers 354∗0.42% = 1.30 billion dollars per year. Adding these up over the 2000-2017 period, the cumulative benefit to consumers is 198.9 $(=\sum_{n=1}^{17} 1.30 \cdot n)$ billion dollars, or an average of 13.3 billion dollars per year. A Korean consumer would save 228 dollars per year by the greater access to new import varieties.[8]

The gain from import variety in South Korea is 2.06% of GDP between 2000 and 2017. The South Korean consumers have gained 2.06% of GDP by the increased import varieties over the 17 years. For example, the South Korean GDP (current $) in 2017 is 1.53 trillion dollars. Hence, the welfare gain is 31.5 billion dollars, the welfare gain per capita is 611 dollars. In 2017, a typical Korean consumer would gain by 611 dollars, compared with 2000. Alternatively, we can interpret the gain via compensation variation. In 2017, South Korean consumers would forego 2.06% of their income to access the expanded variety set in 2017, instead of consuming the variety set of 2000.

[8] The total population of South Korea is obtained from *World Bank* (https://data.worldbank.org/indicator).

5.4 Country Contribution in Variety Gain

In this section we provide the share of the welfare gain stemming from each import country. Using ideal log weights of each country and each good based on the import share in the year 2017, we calculate the country contribution in the welfare gain. Specifically, each importer's EPR is obtained by weighting the lambda ratio for each good by the 'country of interest' weight (import share). Dividing each EPR by the above EPR results in country specific contributions in the South Korean welfare gain.

Table 8. Country Contribution in Variety Gain

Country	Rank	Contribution (%)	Share of Import Value, 2017 (%)	Import Extensive Margin, 2017 (%)
China	1	28.4	20.0	98.1
Japan	2	10.6	11.5	93.9
USA	3	9.32	10.6	92.5
Taiwan	4	3.52	3.77	85.2
Vietnam	5	3.30	3.38	83.7
Germany	6	2.79	4.12	81.9
Singapore	7	2.65	1.86	89.7
Indonesia	8	2.56	2.00	81.8
Thailand	9	2.27	1.08	82.1
Hong Kong	10	1.98	0.39	86.4
Australia	11	1.91	4.09	79.1
Malaysia	12	1.86	1.82	78.8
India	13	1.80	1.03	78.1
Philippines	14	1.68	0.77	79.4
Russia	15	1.64	2.51	64.7
Canada	16	1.63	1.05	69.2
UK	17	1.54	1.32	77.2
Italy	18	1.43	1.19	76.4
Netherlands	19	1.07	1.28	71.7
France	20	1.02	1.20	73.9

Note: The import extensive margin denotes the width of imports from a particular source country.
Source: Author's estimation and calculation using KITA database.

Table 8 lists the top 20 countries' contributions in the welfare gain from import varieties. The country with the largest contribution to the gain over the period is China (28.4%), followed by Japan (10.6) and USA (9.32). About 50% of all the GFVs come from the imports from the 3 countries. Considering that the import share is 20.0% and the import extensive margin from China is 98.1%,[9] not surprisingly, China contributes the largest share. The traditional trading partners, Japan and USA, hold the 2nd and 3rd positions in the list. They are

[9] The import extensive margin denotes the width of imports from a particular source country. Instead of counting the number in the HS codes, we use a more sophisticated measure by Feenstra (1994), and Hummels and Klenow (2005) to incorporate the importance of each import good. The weight used here is the total import value of each good.

still very important to the South Korean welfare gain. The next point to note is that the Southern Asian countries such as Vietnam, Singapore, Indonesia, Thailand, Malaysia, India, and Philippines are more important to the South Korean welfare gain than the Western European countries such as Germany, UK, Italy, Netherlands, and France. The finding that the contributions of the Southern Asian countries are bigger is conforming to the common belief that they have acquired the growing role in the world trade. Interestingly, the contributions of small open economies, Singapore (holding the 7th position) and Hong Kong (holding the 10th position) are so big, considering that the import shares are 1.86% and 0.39%. But South Korea imports 90.7% and 87.4% of its total number of import goods. Oil exporting countries such as Saudi Arabia, Qatar, and Kuwait, holding relatively large shares in South Korean imports, do not belong to the list, even though they are important in terms of import share, not reported. In 2017, they are 5th, 10th, and 11th largest countries in terms of import value, respectively.

6. Conclusion

Recent international studies have largely focused on measuring the welfare gains from increased trade varieties. To adequately capture the variety gains, it is of importance to estimate the elasticity of substitution between varieties of trade goods because it is one of the key parameters to determine the magnitude of the variety gains. Thanks to Feenstra (1994), and Broda and Weinstein (2006), researchers have successfully estimated elasticities of substitution between varieties for ten thousands of goods and measured a welfare gain from trade. It is known that the Feenstra methods and its extension are more tractable and robust than any other method to estimate good-specific elasticities of substitution from highly disaggregated trade data. However, existing studies have chosen one of the methods without any criterion for the choice and then estimated the elasticities of substitution between varieties of trade goods.

This paper has shown that according to the Ramsey RESET and White tests, the F-FGLS estimates are relatively better compared to the F-WLS and BW-FGLS estimates. We provide the first measure of the South Korean consumer gains from import varieties over the period 2000-2017, using the estimated elasticities from the F-FGLS, considered as a suitable estimator. A typical Korean consumer saved 228 dollars per year by the greater access to new import varieties. This leads to gains from imported variety of 2.06% of GDP. In 2017, a typical Korean consumer would gain by 611 dollars, compared with 2000. Lastly, this paper provides the top 20 countries' contributions in the welfare gain from new import varieties. China is the country with the largest contribution (28.4%), followed by Japan and USA. About 50% of all the welfare gains come from the imports from the three main trade partners. The Southern Asian countries are more important to the South Korean welfare gain than the Western European countries, which confirms to the common belief that they have acquired the growing role in the world trade.

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